

ENGINEERING PROPERTIES OF HIGHLY COMPRESSIBLE CLAY STABILIZED WITH POZZOLANIC WASTES

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ABSTRACT

Highly compressible clays are always prone to settlement and subsequent failures. Hence such type of clay deposits needs to be stabilized before commencing any type of construction over it. In the present scenario, accumulation of pozzolanic wastes poses a great threat to environment and human health. Hence their use as stabilizers will not only sort out the problem of their disposal but also enhance their utility in geotechnical engineering works where possible. Locally available highly compressible soil was stabilized by adding 5, 10, 15, 20, 25% of fly ash and rice husk ash as an additive. Effects of stabilization on index properties like shrinkage and compaction and on engineering properties like shear strength and stiffness characteristics were observed and analysed. A general decrease in shrinkage limit of soil was observed when clay was treated with fly ash and rice husk ash. It was observed that OMC increases and MDD decreases when clayey soil was stabilized with rice husk ash. On the other hand, an increase in MDD and decrease in OMC was observed when soil was stabilized with fly ash. No significant trend was observed in shear strength characteristics of stabilized soil. However, a general increase in shear strength was observed when soil was stabilized with fly ash and rice husk ash. A large reduction in compression index and subsequent increase in stiffness was observed with increase in percentage of fly ash and rice husk ash stabilizer.

KEYWORDS: Stabilization, Compaction, Stiffness, Shear Strength and Compression Index

INTRODUCTION

Inadequate strength of soil give rise to settlement problem and a complete failure of structure can be anticipated. Hence it is a responsibility of an engineer or consultant to investigate soil properties before the construction of a structure. If soil beneath a proposed structure is found to be weak then stability of structure can be only be ensured by stabilizing the sub-soil. After stabilization, improved strength ensures that sub-soil can sustain the loads coming from the superstructure, on the other hand, its improved stiffness ensure resistance against undesirable settlements [12]. Stabilization of weak soil deposit is one of the oldest methods to improve its engineering performance. A lot of chemicals as well as fibres are being utilized till now as stabilizers to improve almost every geotechnical property of soil. Choice of these stabilizers depends upon their availability, performance, after-effects and most importantly their cost. In this era of industrialisation, a new problem of waste disposal is arising, which is a great threat to human health as well. Researchers have started utilising these industrial waste materials in stabilizing weak soil deposits. Their use will not only solve the problem of their disposal but also incorporate their utilization in geotechnical engineering works. Also treatment of weak soils by using industrial wastes as an additive is an effective method of stabilization, which is environmental friendly as well [8]. In this study, strength and stiffness characteristics of soil were investigated in order ensure safety of structures after construction. Clay was stabilized with pozzolanic wastes like fly ash and rice husk ash. Index properties like shrinkage limit, compaction and engineering properties like shear strength and stiffness were investigated. The parent soil was cohesive in nature hence

shear strength was evaluated by unconfined compressive strength tests (UCS test). Cohesive soils are prone to settlement hence the samples of clay stabilized with pozzolanic wastes were tested for stiffness by performing one dimensional consolidation tests. Previous studies also suggests that if clayey soils are stabilized properly, they can sustain loads and become suitable for constructing foundations over it[9][10][11].

MATERIALS AND METHODS

Materials Used

Parent Clay

It was collected from Kaithal, Haryana, India. It was classified as CH, highly compressible soil, as per the specification of IS: 1498 (1970) [1] [2]. The grain size distribution and the physical properties are reported in Table1.

Rice Husk Ash

It was collected from Kohinoor Foods Limited, GT Road, Murthal. The material is classified as ML, silt of low compressibility, as per IS: 1498 (1970) [1] [2]. The grain size distribution and the physical properties are reported in Table1.

Fly Ash

It was collected from the first hopper at Panipat Thermal Power Plant, Village Assand, Jind Road, Panipat. Fly ash is classified as ML as per IS: 1498 (1970) [1] [2]. The grain size distribution and the physical properties are reported in Table1.

Table 1: Index Properties of Materials

Physical Properties	Materials		
	Parent Clay	Rice Husk Ash	Fly Ash
Gravel (%)	0	0	0
Sand (%)	6.75	23.22	7.5
Clay + silt (%)	93.25	76.78	92.5
Specific gravity	2.48	1.95	2.09
Liquid limit	54	NP	NP
Plastic limit	25		
Plasticity index	29		
Is classification	CH	ML	ML
OMC (%)	14.71	-	-
MDD (g/cc)	1.93	-	-

Sample Preparation

Composition of Specimens

Specimens of parent clay and clay treated with 5, 10, 15, 20 and 25% by weight of various pozzolanic waste materials passing 425 micron IS sieve were prepared at maximum dry density and optimum moisture content as per IS: 2720 (Part 7) (1974) [3].

Mixing

Oven dry soil was dry mixed with various percentages of additives. Sufficient quantity of water was then added to bring the moisture content to the desired level. The mixture was then manually mixed thoroughly with a spatula. All the specimens were kept in polythene bags for maturing for five days.

Compaction

Consolidation Test

Cylindrical specimens were compacted by static compaction in 10 cm diameter consolidation ring to the required height of 2.5 cm. The inner surface of the ring was smeared with mobile oil to help minimize friction between inner surface of the ring and the soil sample during consolidation process. The wet homogenous mixture was placed inside the specimen ring using spoon and levelled. Sample was placed in specimen ring with extension collar attached to it and both the exposed sides of the sample were covered with filter papers. After that porous stone and pressure pad were inserted into the extension collar and the whole assembly was statically compacted in loading frame to the desired density. The sample was kept under static load for not less than 20 minutes in order to account for any subsequent increase in height of sample due to swelling.

UCS Test

Cylindrical specimens were compacted by static compaction in 3.9 cm diameter split mould to the required height of 8.5 cm. The inner surface of the split mould was smeared with oil to reduce friction during the extraction of sample. The wet homogenous mixture was placed inside the split mould using spoon with continuous tapping with spatula and levelled. The whole assembly was statically compacted in loading frame to the desired density. The sample was kept under static load for not less than 20 minutes in order to account for any subsequent increase in height of sample due to swelling. All the specimens were kept in polythene bags for maturing for three days. Figure 1 shows a sample of soil prepared for unconfined compressive strength test.



Figure 1: Sample Prepared for UCS Test

RESULTS

The objective of the present study is to investigate shear strength and stiffness characteristics of highly compressible locally available clay soil treated with 5, 10, 15, 20 and 25% by weight of fly ash and rice husk ash. This has been done to make the soil suitable for foundation constructions or sub-grades over it. In order to assess improvement in stiffness, coefficient of compressibility have been evaluated from the results of one-dimensional consolidation tests conducted at stress levels of 0.25, 0.5, 1.0, 2.0 and 4.0 kg/cm². For the evaluation of shear strength parameters UCS (unconfined compressive strength test) were performed on various soil samples stabilized with fly ash and rice husk ash. The results of these tests have been analyzed under the following headings:

Shrinkage Limit Analysis

Shrinkage limit is the water content of the soil when the water is just sufficient to fill the pores of the soil and the soil is just saturated. The volume of the soil does not decrease when the water content is reduced below the Shrinkage limit. It was observed that shrinkage limit of clayey soil decreases from 36.52% to 16.13% with increase in percentage of

pozzolanic waste as stabilizer. The test was performed as per the specifications of IS: 2720 (Part 6) (1972) [4]. These observations were attributed to the reaction of free lime content present in fly ash and rice husk ash with clay. Figure 2 below shows the variation of shrinkage limit with various percentages of pozzolanic wastes.

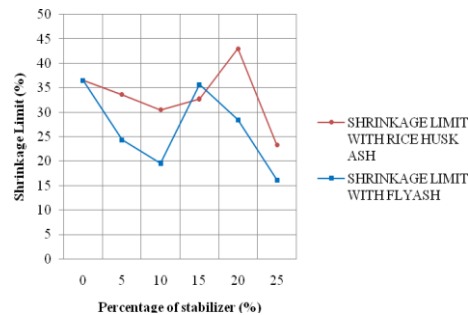


Figure 2: Shrinkage Limit vs. Percentage of Stabilizer

Moisture- Density Relationships

Values of optimum moisture content (OMC) and maximum dry density (MDD) for parent clay were found to be 14.71% and 1.93 g/cc.

It was observed that with increase in percentage of rice husk ash as stabilizer the value of OMC increases from 14.71% to 32.5% and value of MDD decreases from 1.93 g/cc to 1.54 g/cc. On the other hand, when fly ash was mechanically mixed with parent clay, no significant changes were observed in the values of OMC and MDD. Generally OMC increases and MDD decreases in case of fly ash stabilized clay samples. This significant increase in optimum moisture content can be attributed to water absorbing tendency of rice husk ash that too present in fly ash in small quantity. Decrease in MDD of stabilized samples can be attributed to the addition of a material of low specific gravity to parent clay. Figure 3 and Figure 4 represent the variation of MDD and OMC with percentage of stabilizer respectively.

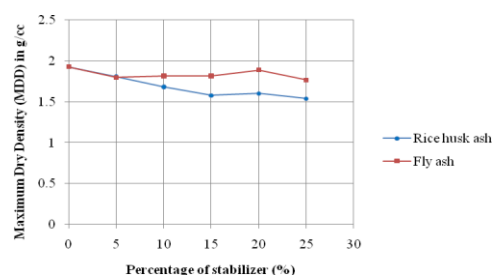


Figure 3: MDD vs. Percentage of Stabilizer

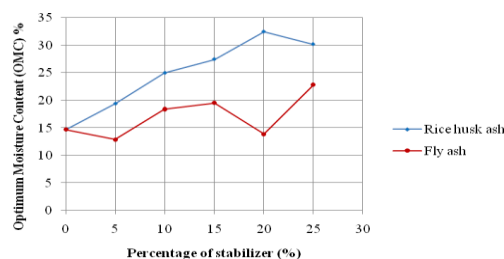


Figure 4: OMC vs. Percentage of Stabilizer

Stiffness

Based on the analysis of pressure-void ratio curves on semi-log plot, compression index (C_c) values, for all stabilized clay samples were determined as per the specifications of IS: 2720 (Part 15) (1986) [6]. The value of C_c for

parent clay has been determined as 0.458. It has been observed that values of C_c vary from 0.508 to 0.181 for various percentages of rice husk ash. A general decrease in value of C_c with an increase in rice husk ash content. Reduction in value of compression index results in increased stiffness. This may be attributed to the increased tendency of soil treated with rice husk ash to resist compression due to the formation of pozzolanic products within the voids. The values of C_c vary from 0.441 to 0.326 for various percentages of fly ash. It was observed that there is a decrease in value of C_c with an increase in fly ash content. This may be attributed to the addition of non-plastic silty material to parent clay.

It has been observed that out of the two pozzolanic wastes, rice husk ash is more helpful in reducing consolidation settlement of the parent soil over a large range of effective stresses. These values of C_c for soil treated with various percentages of pozzolanic wastes will help in proper designing of the foundation on the basis of settlement criteria [7].

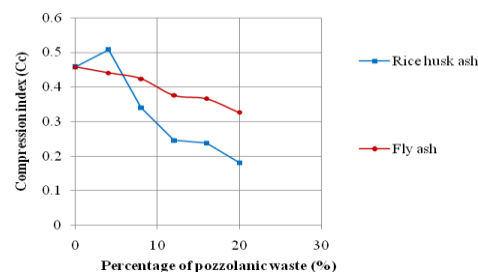


Figure 5: Compression Index vs. Percentage of Pozzolanic Waste

Strength Characteristics

A series of unconfined compressive strength tests were conducted to determine the strength characteristics of parent clay treated with various percentages of pozzolanic wastes as per specifications of IS: 2720 (Part 10) (1973) [5]. It was observed that shear strength of clayey soil stabilized with rice husk ash varies from 3.36 N/Cm² to 3.85 N/Cm². While shear strength of clayey soil stabilized with fly ash varies from 3.36 N/Cm² to 3.65 N/Cm². Stress – strain relationships for clay and clay stabilized with various percentages of pozzolanic wastes are shown in Figure 6 to Figure 16 below.

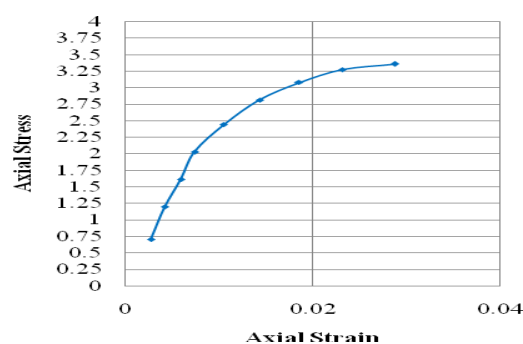


Figure 6: Stress- Strain Relationship for Parent Clay

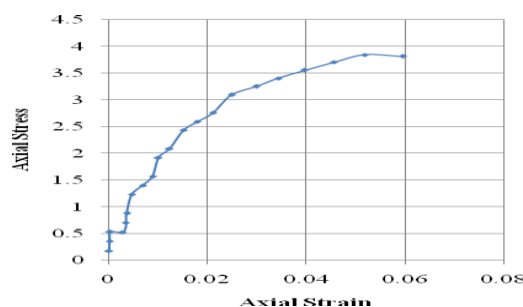


Figure 7: Stress- Strain Relationship for Parent Clay Stabilized with 5% Rice Husk Ash

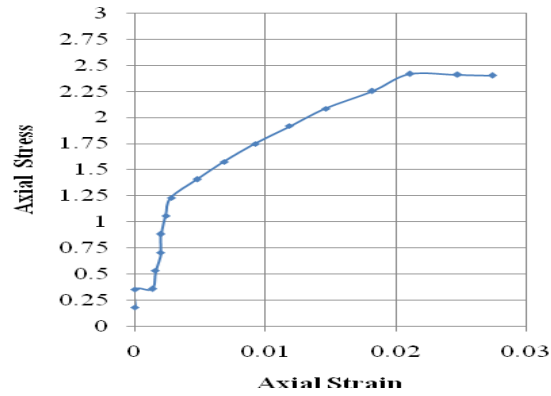


Figure 8: Stress- Strain Relationship for Parent Clay Stabilized with 10% Rice Husk Ash

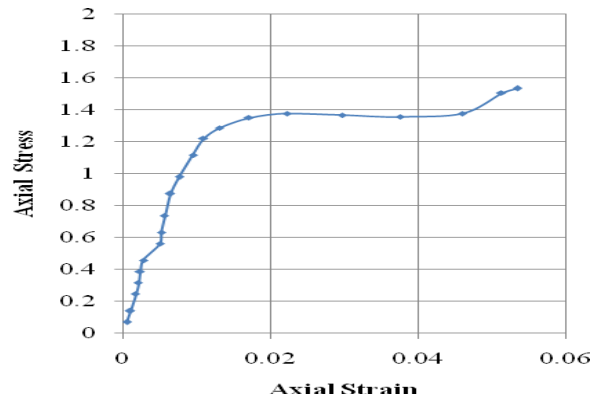


Figure 9: Stress- Strain Relationship for Parent Clay Stabilized with 15% Rice Husk Ash

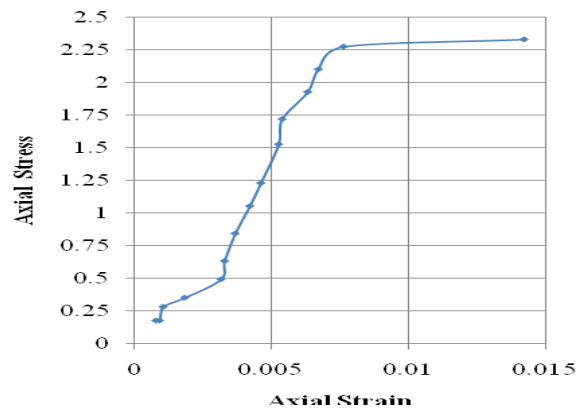


Figure 10: Stress- Strain Relationship for Parent Clay Stabilized with 20% Rice Husk Ash

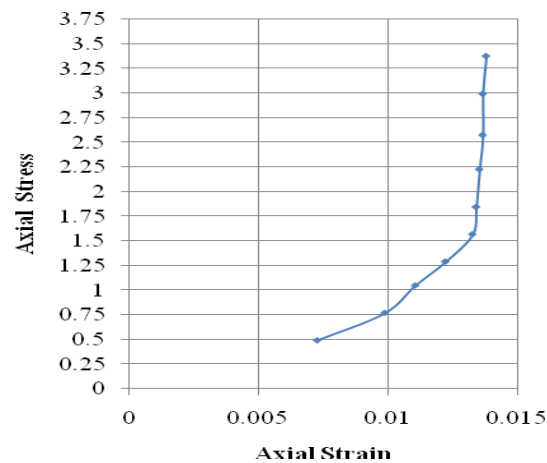


Figure 11: Stress- Strain Relationship for Parent Clay Stabilized with 25% Rice Husk Ash

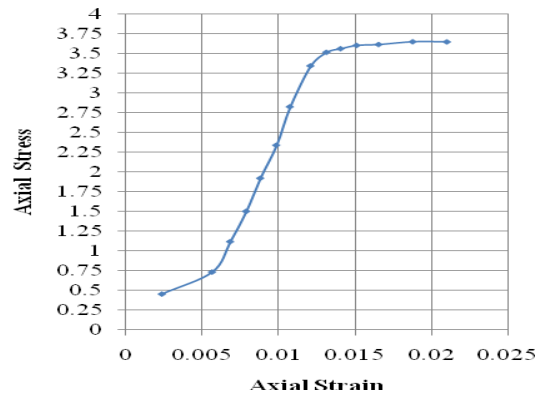


Figure 12: Stress- Strain Relationship for Parent Clay Stabilized with 5% Fly Ash

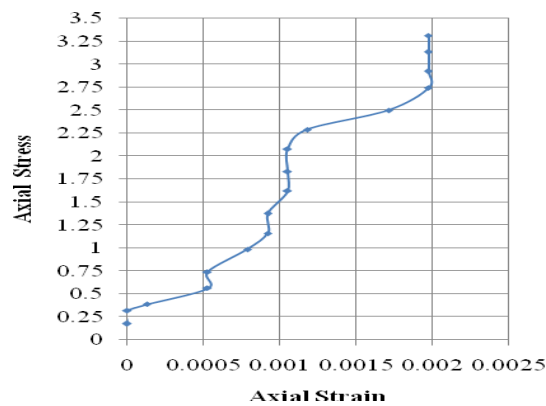


Figure 13: Stress- Strain Relationship for Parent Clay Stabilized with 10% Fly Ash

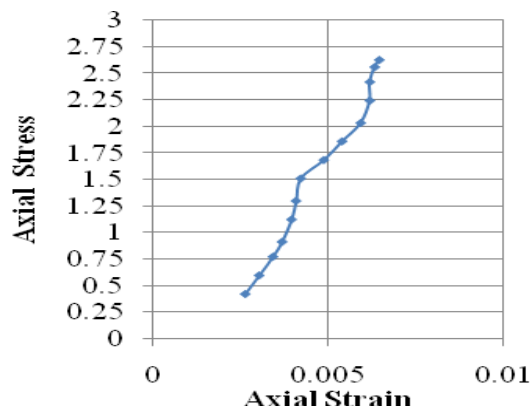


Figure 14: Stress- Strain Relationship for Parent Clay Stabilized with 15% Fly Ash

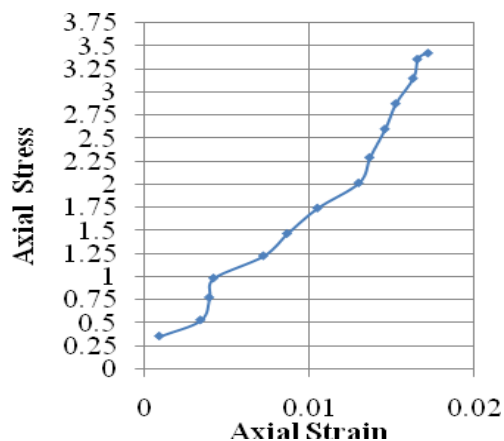


Figure 15: Stress- Strain Relationship Parent Clay Stabilized with 20% Fly Ash

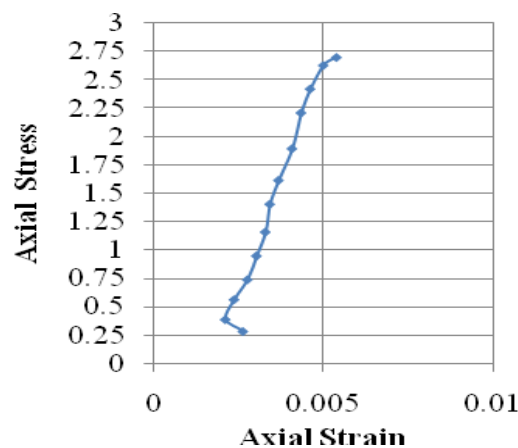


Figure 16: Stress- Strain Relationship for Parent Clay Stabilized with 25% Fly Ash

CONCLUSIONS

The study demonstrates the influence of rice husk ash and fly ash on the shrinkage, stiffness and strength characteristics of highly compressible locally available clay. The following conclusions have been drawn based on the laboratory investigations carried out in this study:

- A considerable decrease in values of shrinkage limit was observed when soil was stabilized with fly ash and rice husk ash.
- Compaction characteristics show no significant trend for the range of percentage of fly ash as stabilizer. However, significant decrease in MDD and increase in OMC was observed for clay samples stabilized with rice husk ash.
- The use of rice husk ash and fly ash as additives lowers the slope of virgin compression curves, thereby reducing the values of C_c and subsequent increase in stiffness.
- It has been observed that out of the two pozzolanic wastes, addition of rice husk ash is more helpful in reducing compression index and hence decreasing the consolidation settlement of the parent soil and increasing stiffness.
- A general increase was observed in the strength when soil was stabilized with fly ash and rice husk ash. However, the trend was insignificant.

Similar results were observed by various investigators in studies [8][9][10][11]. The study shows that treatment of soil with rice husk ash and fly ash is an effective method of stabilization of problematic soils. Results of this study can be used in designing foundations on compacted stabilized clay beds [7].

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